ELECTRO-ENCEPHALOGRAPHIC AND BLOOD GAS OBSERVATIONS IN HUMAN SURGICAL PATIENTS DURING XENON ANESTHESIA • † ‡

LUCIEN E. MORRIS, M.D.,§ JOHN R. KNOTT, M.D.,|| AND CHARLES B. PITTINGER, M.D.||

Seattle, Washington

Since the report of the anesthetic properties of xenon by Cullen and Gross in 1950 (1), many studies have been carried out to determine the effects and the action of this gas during its clinical use. In the course of these studies, it became apparent that it would be of interest to determine the changes which could be noted in the electro-encephalogram during xenon anesthesia, and to compare these with previously reported changes during the course of anesthesia with other inhalation agents (2-4).

Seven patients subjected to surgical intervention were anesthetized with xenon by a modified closed absorption technique which has been described previously (5). Brief descriptions of these cases are as follows:

CASE REPORTS

Case 1. 1-26-53, M. S. Female, aged 35. Hb. 13.0; R.B.C. 5.14; W.B.C. 3850.

Diagnosis: Carcinoma of cervix.
Operation: Insertion of Ernst radium.

The only preanesthetic medication given was 0.3 mg. of scopolamine I.M. seventy-five minutes before the beginning of xenon anesthesia. Fifteen minutes of very satisfactory light anesthesia was provided with xenon, during which there was no evidence of stimulation of the patient. There was no excitement during induction and the patient awakened within two minutes following discontinuance of xenon.

* Accepted for publication February 4, 1955.
† This project was supported in part by a research grant to Drs. Stuart C. Cullen, E. G. Gross, and R. M. Featherstone, of the State University of Iowa, College of Medicine, from the U. S. Public Health Service (G-3362). The xenon was supplied through the courtesy of the Linde Air Products, Inc.
‡ The authors are indebted to Dr. Jack Hummel for the provision of the blood gas determinations. They are also appreciative of the technical assistance in recording electro-encephalograms given by Mr. Jack F. Morgan.
§ Formerly of the Division of Anesthesiology, College of Medicine, State University of Iowa; present address, Division of Anesthesiology, School of Medicine, University of Washington, Seattle, Washington.
|| Department of Psychiatry, College of Medicine, and the Psychopathic Hospital, State University of Iowa, Iowa City, Iowa.
|| Department of Surgery, Division of Anesthesiology, and the Department of Pharmacology, College of Medicine, State University of Iowa, Iowa City, Iowa.

312
Observations during Xenon Anesthesia

May, 1955

Case 2. 1–26–53, E. J. Female, aged 30. Hb. 13.0; blood pressure on examination, 122/70.

Diagnosis: Pregnancy at term, pelvic disproportion (2 previous sections).

Operation: Extraperitoneal cesarean section with ligation of tubes.

Preeanesthetic medication, 0.2 mg. of scopolamine I.M. one hour before anesthesia. On arrival in the operating room, her blood pressure was 115/70. This patient had a copious emesis during induction, which led to partial obstruction and temporary laryngospasm. After a brief interval, it was decided that it would be wise to facilitate the airway and also to reduce to a minimum the loss of xenon by the use of an endotracheal tube. In order to accomplish this quickly and easily, the patient was given 18 mg. of d-tubocurarine, following which the closed system was reestablished and the operation allowed to begin. During the interval of partial obstruction, the blood pressure rose briefly to 140/80, but quickly returned to normal. Satisfactory and otherwise uneventful anesthesia was provided with xenon for 1 hour and fifty-five minutes. Fifty-five minutes after the beginning of xenon and forty-two minutes after the injection of curare, a male infant was delivered who cried lustily and spontaneously before complete removal from the uterus. There was no evidence of any depression. The patient was awake within two minutes after removing the mask from her face, but she appeared somewhat lethargic. This may have been due to some residual effect of the curare. However, on command she could raise her head from the pillow easily and well.


Preoperative diagnosis: Postmenopausal bleeding, vaginitis, paralysis agitans.

Operation: D and C.

Preeanesthetic medication, 0.2 mg. of scopolamine at 0800. Due to some unexpected changes in the operative schedule, anesthesia with xenon did not begin until 11:55 a.m. No additional premedication was given. Anesthesia was maintained for twenty-two minutes, being uneventful and very satisfactory for the surgical procedure.

Case 4. 5–20–53, V. E. Female, aged 28.

Diagnosis: Menorrhagia.

Operation: D and C.

Preeanesthetic medication, 0.3 mg. of scopolamine subcutaneously, at 9:00 a.m. The blood pressure of this patient when she came into the operating room was recorded as 80/40, pulse 74, respirations 18. Xenon anesthesia was begun at 10:48 a.m. Anesthesia was quite satisfactory for the operative procedure, which took approximately half an hour. In spite of copious intrauterine bleeding, blood pressure, pulse, and respiration remained quite consistently at the preanesthetic levels. At the close of the procedure and closely correlated with uterine packing, there was some retching and a small amount of emesis.

Case 5. 5–13–53, B. J. Male, aged 67.

Diagnosis: Right inguinal hernia.

Operation: Hernioplasty.

Patient also was emphysematous and had had a recent upper respiratory infection. Preoperative blood pressure, 170/110. Preeanesthetic medication, 8.0 mg. of morphine sulfate, 0.3 mg. of scopolamine, at 7:00 a.m. When patient arrived in the operating room, blood pressure was recorded at 130/80, pulse
60, respirations 18. Xenon anesthesia was begun at 9:18 a.m. There was a marked excitement period during induction. The operative incision was made at 9:38 a.m. The patient was anesthetized quite lightly. Because of lack of relaxation satisfactory to the continuance of the surgical procedure, 50 mg. of demerol® was given intravenously at 9:48 a.m. The remainder of the operative procedure was conducted under quite satisfactory conditions until completion at 10:40 a.m. Blood pressure and pulse remained stable throughout the procedure. The patient awoke somewhat more slowly than the other patients in the series and did not become alert until approximately nine minutes after removal of the mask.

Case 6. 3-4-53, S. G. Female, aged 53. Hb. 7.0; R.B.C. 4.36; W.B.C. 11,100; blood pressure on examination, 122/70.

Diagnosis: Recurrent carcinoma of the cervix, with extension into bladder and vagina. A recent vaginal hemorrhage had occurred.

Operation: Biopsy of the vaginal wall.

Preanesthetic medication, 0.3 mg. of scopolamine at noon. Blood pressure on arrival in the operating room, 100/50, pulse 90. Xenon anesthesia began at 12:54 p.m.; operation began at 1:01 p.m. Satisfactory and uneventful anesthesia was provided with xenon for a total of eighteen minutes. Blood pressure, respiration; and pulse remained stable throughout. There was prompt recovery with no complications.

Case 7. 2-25-53, J. D. Female, aged 56. Hb. 14.5; weight, 212 pounds; blood pressure on examination, 160/90. No other contributory findings.

Diagnosis: Carcinoma of the uterus.

Operation: D and C and insertion of body radium.

Preanesthetic medication, 0.3 mg. of scopolamine by hypodermic injection at 9:00 a.m. Due to some delay in the operating schedule, xenon anesthesia was not begun until 11:04 a.m. On arrival in the operating room, patient’s blood pressure was 110/70, pulse 60, respirations 16. Operation was begun at 11:17 a.m. Anesthesia with xenon was maintained until 11:52 a.m. Patient appeared very lightly anesthetized much of the time. There was one episode of retching during the anesthesia but there was no emesis. Blood pressure and pulse remained steady throughout but there was a slight increase in respiratory rate to 22 per minute correlated with the surgical stimulation. Patient awoke quickly at the end of procedure.

Method.—Electroencephalograms were obtained using electrodes secured with collodion on the vertex and on one ear. The equipment used was a Grass model III C electro-encephalograph. Continuous recordings of both electro-encephalograms and electrocardiogram tracings were made from a time before the induction of anesthesia until after the patients had regained consciousness. The electro-encephalogram records were visually analyzed by consecutive minutes and the range of frequencies as well as the dominant frequency determined. In this way, it was possible to depict the variability which would occur not only from minute to minute but also within any minute. Qualitative estimates of amplitude changes were also noted.

Blood samples were taken before anesthesia and at variable intervals during anesthesia to determine blood oxygen and carbon dioxide values. Frequent sampling of the respired atmosphere through
a Beckman oxygen analyzer provided close monitoring of the partial pressure of oxygen in the gas mixture. The percentage of oxygen in the gas mixture offered to the patients was maintained at approximately 20 per cent at all times.

Fig. 1. Selected positions of the EEG tracing: (1) Patient breathing air prior to anesthesia; (2) 4 minutes after start of Xe; (3) 10½ minutes after start of Xe; (4) 18 minutes after start of Xe; (5) 28 minutes after start of Xe; (6) 68 minutes after start of Xe; (7) 7 minutes after discontinuation of Xe anesthesia—patient now responding.
Results.—Satisfactorily interpretable electro-encephalograms were obtained on 6 patients. The analysis of these records revealed continuous activity between 5 and 250 microvolts with all frequencies represented during the course of anesthesia. There was a relatively constant course of EEG change with an initial depression of alpha activity (8 to 13/sec.) and a low-voltage fast pattern in the initial stage followed by a rhythmic 5 to 7/sec. pattern mixed with other frequencies. As the clinical level of anesthesia presumably became deeper, there tended to be some increase in random 2 to 3/sec. activity and a more prominent 4 to 5/sec. activity, but the higher frequencies continued to be apparent. These changes are illustrated in figure 1, which shows selected tracings from one patient during the course of anesthesia. In figures 2 and 3, there are presented graphically for 2 of the patients the dominant patterns and the range of frequencies together with changes in heart rate, blood pressure, and partial pressure of oxygen in the respired atmosphere.
Fig. 3. Changes in EEG frequency range, dominant frequency, blood pressure, heart rate, and partial pressure of oxygen in the respired atmosphere during xenon anesthesia; note the persistence of the high-frequency EEG rhythms throughout the anesthesia.

Electrocardiographic changes were relatively minimal throughout these anesthetics, and none as observed which could be ascribed to the xenon itself. Premature ventricular contractions were observed in 3 of the 7 patients, 2 of which had similar pre-existing conduction abnormalities. In the third instance, a few premature ventricular beats occurred at the time of emesis and brief partial obstruction (Case 2).

Blood oxygen and carbon dioxide determinations as shown in table 1 are within normal ranges, indicating good oxygenation and adequate ventilation for removal of carbon dioxide.

Discussion.—There is a striking difference between the electroencephalographic changes observed with xenon and the electroencephalographic results correlated with other anesthetic agents as described by others. Xenon does not seem to produce a very slow, single rhythmic pattern of the type described for ether (2) or cyclopropane (3). Whereas it appears to have been possible for other workers to
TABLE 1

BLOOD GAS ANALYSES OBTAINED FROM SAMPLES TAKEN BEFORE AND DURING XENON ANESTHESIA

<table>
<thead>
<tr>
<th>Patient</th>
<th>Before Anesthesia</th>
<th>Arterial</th>
<th>Venous</th>
<th>After 15 min. or More of Anesthesia with Xenon</th>
<th>Arterial</th>
<th>Venous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>( O_2 )</td>
<td>( CO_2 )</td>
<td>( O_2 )</td>
<td>( CO_2 )</td>
<td>( O_2 )</td>
</tr>
<tr>
<td>1. M. S.</td>
<td></td>
<td>—</td>
<td>—</td>
<td>17.4</td>
<td>66</td>
<td>—</td>
</tr>
<tr>
<td>2. E. J.</td>
<td></td>
<td>—</td>
<td>—</td>
<td>10.5</td>
<td>51</td>
<td>21.7</td>
</tr>
<tr>
<td>3. M. W.</td>
<td></td>
<td>—</td>
<td>—</td>
<td>12.0</td>
<td>56.8</td>
<td>20.1</td>
</tr>
<tr>
<td>4. V. E.</td>
<td></td>
<td>16.1</td>
<td>51.6</td>
<td>11.0</td>
<td>54.1</td>
<td>19.8</td>
</tr>
<tr>
<td>5. B. J.</td>
<td></td>
<td>20.1</td>
<td>65.6</td>
<td>13.1</td>
<td>73.9</td>
<td>—</td>
</tr>
<tr>
<td>6. S. G.</td>
<td></td>
<td>—</td>
<td>—</td>
<td>10.3</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>7. J. D.</td>
<td></td>
<td>—</td>
<td>—</td>
<td></td>
<td></td>
<td>—</td>
</tr>
</tbody>
</table>

define some 6 (cyclopropane) or 7 (ether) electroencephalographic levels, with xenon no more than 3 levels were observed. In no case were "suppression," or "burst-suppression," effects seen. In addition, it is noteworthy that the slower frequency of the dominant activity associated with clinical anesthesia produced by xenon is appreciably faster than the slow activity described as being characteristically associated with cyclopropane and ether anesthesia. It should be pointed out that the observations reported here were in patients in whom the supplemental use of potent analgesics and barbiturates had been avoided (except in case 5).

In general, it could be ascertained from the EEG when a change in the level of anesthesia was about to occur; the electroencephalographer usually was able to make the prediction several seconds in advance of the clinical event. This was achieved by evaluation of the amount of activity and to some extent by the voltage, in the 6/sec. and slower bands. As such activity increased, anesthesia deepened; as it decreased, lighter levels of anesthesia prevailed. This activity might be used to operate a servo-system for automatic control of xenon anesthesia, but, in our opinion, it would require further extensive research before one could state that such control would be practical.

In spite of the fact that the EEG changes were not so marked nor so dramatic as those described for other inhalation agents, the clinical levels of anesthesia achieved, although very light, were sufficient for the surgical purposes (except case 5, which was improved by the administration of a small amount of demerol).

Summary.—Satisfactory xenon anesthesia was provided to 7 patients for surgical intervention. Although characteristic EEG changes were observed during anesthesia with xenon, the degree and the character of the changes appeared to be different from those described for other inhalation agents.
May, 1955

OBSERVATIONS DURING XENON ANESTHESIA

REFERENCES


